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Electrical Positive Yarn Feeding Device

The invention relates to a yarn delivery device, which is in particular suitable for the positive delivery of yarn to knitting machines, for example circular knitting machines.

In connection with knitting machines, also with circular knitting machines, the stitch size of the stitches to be created by the individual knitting systems is set by means of a precise apportioning of the yarn running into the knitting stations. For knitting smooth goods, this principle is well established by using mechanically driven yarn feeding devices. In this connection an electrical or electronic replacement of the rigid mechanical coupling between the yarn delivery device and the knitting machine has long been sought.

For example, USP 3,858,416 discloses a knitting machine with an electrical yarn feeding device, which can be alternatingly driven in a voltage-regulated manner or synchronously with the main cylinder. For performing the latter type of operation, a magnetic or other type of sensor is provided at the main drive mechanism of the knitting machine, which generates a sequence of pulses whose frequency corresponds to the speed of the knitting machine. A frequency/voltage converter converts these pulses to a voltage, which then is characteristic of the operating speed of the knitting machine.

The motor driving the yarn feed wheel is connected with a tachometer generator, which is also connected to a frequency/voltage converter in order to provide a voltage which is characteristic of the rpm of the motor. A comparator circuit compares the voltages delivered by both frequency/voltage converters and controls the motor of the yarn feeding device accordingly.

Deviations between the desired deliveries and actual deliveries can occur in principle in connection with such arrangements, which have an effect on the quality of the knit goods.

It has been attempted in various ways to drive yarn delivery wheels electrically. For example, DE 38 24 034 C1 discloses the driving of a yarn delivery wheel by means of a step motor.

It is not possible to switch step motors arbitrarily on and off. Instead, it is necessary to maintain a defined operating regimen when starting as well as slowing down, so that no step errors occur.

Further efforts can be found in DE 15 74 430 for delivering tape- or strip-shaped material, in particular yarn, to a user location at a preset speed. An electrical drive motor is provided to this end, whose shaft is connected with a delivery wheel. Here, a clutch device allows an arbitrary connection and disconnection of the delivery wheel from the drive motor. The delivery wheel is used as the rpm measuring device. Voltage meters are arranged upstream and downstream of the delivery wheel. In a set-up mode of operation the delivery wheel is uncoupled from the motor shaft and the rpm of the yarn delivery wheel then occurring are registered in order to be made the basis for the later operation of the motor.

The activation of the clutch is required for taking up the set-up operation. Resisting devices provided in the path of the yarn also act in a braking manner on the yarn. Therefore, in the case of knitting machines the amount of yarn provided is affected by chance. The clutch has a moment of mass inertia, which is added to the moment of mass inertia of the yarn delivery wheel and of the motor.

Based on the foregoing, it is the object of the invention to create a yarn delivery device suitable in particular for knitting machines, particularly for knitting machines with changing yarn requirements, and allows a high degree of delivery quality in the process.

This object is attained by means of the yarn delivery device in accordance with claim 1.

The yarn delivery device in accordance with the invention has a yarn delivery wheel which is rigidly connected with an electric motor and has a predetermined diameter. In

this case the yarn delivery wheel can have a round, as well as a polygonal cross section. For example, it can be in the form of a rod cage. An alternative is a one-piece yarn delivery wheel, deep-drawn from sheet metal, whose circumference is provided with longitudinal ribs, for example, so that it mimics the outer contours of a rod cage. Other yarn delivery wheels are also possible. It can be enveloped by a lap resting against the entire circumference. But the lap can also touch only a portion of the delivery wheel circumference and can be conducted, for example, over (fixed or stationary) lift-off pins. An angle encoder, which is connected with the yarn delivery wheel in a manner fixed against relative rotation, is furthermore provided, which generates a signal which identifies every rotated position of the yarn delivery wheel. In this case a high angular resolution is essential, which is at least high enough so that the ratio between the number of steps of the angle encoder and the diameter of the yarn delivery wheel is greater than three per millimeter. By angular resolutions above this threshold limit the yarn delivery wheel can be positioned so accurately that synchronous running between the yarn delivery wheels and the knitting machine is achieved in all essential operational states of the knitting machine. If the angular resolution of the angle encoder is higher than the mentioned value, and if the rotatory position of the motor is correspondingly set in a position regulation loop, it is possible to start up, as well as stop, a knitting machine with an electronic positive feeding device, without the production of standing rows, which otherwise would have to be feared. Standing rows are understood to be rows of stitches having a different size than the remaining stitches in the knit material.

Preferably the angle encoder is connected with the shaft of the motor, wherein a shaft extending through the motor is provided in a preferred embodiment, at whose one end the yarn delivery wheel is arranged and on its other end the angle encoder. The angle encoder preferably is an incremental encoder with a high increment number. At a diameter of 40 mm,

the angle encoder has at least 120 steps, i.e. an angular resolution of at least 3°. Embodiments are preferred, wherein the ratio s/d (number of steps to the diameter of the delivery wheel) is greater than five. ("the number of steps" is understood to be the number of steps which can be distinguished during one revolution by means of the angle encoder). In such a case the angle encoder has a resolution of more than 200 steps per revolution of the delivery wheel. This corresponds to a resolution of at least 1.8° or better. In the preferred case s/d is greater than 5:24. In this way delivery accuracies regarding the yarn delivery are obtained from the position regulation loop, regardless of the respective yarn delivery wheel diameter, in which delivery deviations are less than 0.6 mm. This results in error-free knitted goods, even if the operating speed of the knitting machine is changed, i.e. it stops or starts.

In this way an electronic positive yarn feeding device is created by means of the high-resolution angle encoder, which not only provides precise deliveries, but moreover can be remotely controlled. For example, when producing patterned knit goods, it can be switched on and off in a specific manner. In this way the electronic positive yarn feeding device in accordance with the invention renders obsolete friction-type yarn feeding devices, which up to now had been used for this purpose. It allows an improved control of the stitch size when producing patterned goods. In a preferred manner the electronic positive yarn feeding device is provided with a pulse sequence as the control signal, wherein each one of the pulses corresponds to an angle step of the yarn delivery wheel. For example, the angle step corresponds to an angle step which corresponds to the angular resolution of the position sensor. Preferably it is of such a size that it corresponds to a yarn delivery path of 1 mm, preferably 0.6 mm. With each step received by the yarn delivery device, the latter rotates the yarn delivery wheel forward by a yarn length of 0.6 mm. A continuous control of the amount of the delivery corresponding to the rotation of the main cylinder of the knitting machine is

possible in this way. The positionally-controlled feeding device virtually acts in the same way as a step motor- driven feeding device, wherein its position control loop prevents the occurrence of step errors.

The yarn delivery device can preferably house a position regulating device,. which always compares the angular position of the yarn delivery wheel detected by the angle encoder with a desired signal and corrects deviations. In an expanded embodiment the position regulating device can also be the part of a regulating device for the traction tension. In this case a yarn tension sensor is additionally provided, which detects the actual tension of the yarn. If this deviates from a predetermined desired tension value, appropriate positioning signals are generated, which are then converted by the position regulating device. In this case the tension regulating device is embodied as a PD regulator with disturbance variable compensation. This means that the regulator has a proportionally amplifying portion ("P"), as well as a differentiating portion ("D"). A correcting value is determined from the detected yarn tension, from the actual delivery speed, and possibly from the motor currents, and is linked with the desired tension value in order to correct it in such a way that permanent regulation deviations caused by the regulating device disappear.

In a further development, the yarn delivery device in accordance with the invention has a first mode of operation, in which it operates, depending on its embodiment, as a positive yarn feeding device either tension-regulated or positionally regulated. In an additional mode of operation, which can be called a dragging mode of operation, the current of the electric motor is reduced to such an extent that it no longer provides active yarn feeding. In this case the motor current is set in such a way that all possible locking moments of the electric motor are overcome and no drive moment is generated, or at most a drive moment which is not sufficient for feeding yarn. As far as the yarn-processing machine is concerned, no positive yarn feeding device exists in this operational state.

Instead, the yarn-processing machine is required to obtain yarn from a yarn source, for example a bobbin creel. In this case the drive moment of the electric motor is at most sufficiently large so that this process is made easier. In this case the force for pulling the yarn off the bobbin creel is only partially provided by the yarn feeding device. Thus the yarn delivery wheel is virtually disengaged from the motor shaft, at least to the extent that it does not provide any feeding. The yarn-processing machine, or its knitting system, can pull in the yarn against a small resistance. A circuit connected to the electric motor, or the incremental encoder, can precisely detect the amount of yarn obtained and make it the basis for the further operation of the yarn delivery device in the positive yarn-feeding mode.

Details of advantageous embodiments of the invention are the subject of the drawings, the specification or the claims. Exemplary embodiments of the invention are illustrated in the drawings. Shown are in:

Fig. 1, several electronic, positionally-regulated yarn feeding devices and their connection to a central control device, in a schematic representation,

Fig. 2, the yarn feeding devices designed as tension-regulated yarn feeding devices, connected to a central control device, in a schematic representation,

Fig. 3, the yarn feeding devices in accordance with Fig. 1 with an additional dragging mode of operation, connected to a central control device in a schematic representation,

Fig. 4, an angle encoder of a yarn feeding device in a schematic representation,

Fig. 5, output signals of the angle encoder in accordance with Fig. 4,

Fig. 6, an alternative embodiment of an angle encoder in a schematic representation,

Fig. 7, a tension-regulated yarn feeding device with disturbance variable compensation in a schematic representation, and

Fig. 8, a modified angle encoder in a schematic

perspective representation.

A group of yarn delivery devices 1, 2, 3, which are connected to a central control device 4, is illustrated in Fig. 1. The control device 4 can be a central control device, it can be part of a knitting machine, be a separate device or can be housed in one of the yarn delivery devices 1, 2, 3. The yarn delivery devices 1, 2, 3 are represented merely by way of example. If required, only a single yarn delivery device 1 or a larger group of yarn delivery devices can be provided.

The number of the yarn delivery devices 1, 2, 3 corresponds to the number of yarns to be delivered to a yarn-processing machine, for example a circular knitting machine, and therefore to the number of knitting stations. They are substantially identically constructed in respect to each other. Thus, the subsequent description of the yarn delivery device 1 correspondingly applies to the remaining yarn delivery devices, as well as possibly further, non-represented yarn delivery devices.

The yarn delivery device 1 has a yarn delivery wheel 5 constituted, for example, by a deep-drawn sheet metal element. At the top and bottom it can respectively be provided with an outwardly projecting edge 6, 7, which constitutes a yarn inlet area and a yarn outlet area. A yarn storage area arranged between them can be provided with ribs 8. Yarn guide means, such as, for example, a yarn inlet eye, a yarn outlet eye, a yarn brake, a knot catcher and the like are arranged upstream and downstream of the yarn delivery wheel 5. Moreover, yarn feeler levers or other yarn monitoring devices can be provided as required.

A yarn is looped around the yarn delivery wheel 5 with a least one, preferably several laps 11. The lap 11 comprises at least one, however preferably several windings 12. In the course of a rotation of the yarn delivery wheel 5, the yarn 9 runs onto the storage area of the yarn delivery wheel at the upper edge 6, in the process forms side-by-side located windings and, because of this, pushes the lap 11 axially downward. The yarn delivery wheel 5 can have a slight conicity

for making this process easier. With the yarn delivery wheel 5 running, the lap 11 is therefore continuously in movement on the yarn delivery wheel 5.

The yarn delivery wheel 5 is connected with a shaft 13, which is part of an electric motor 14. The connection is fixed against relative rotation and preferably cannot be released by operationally controllable means, such as clutches or the like. The electric motor 14 preferably is a brushless d.c. motor with a low moment of mass inertia, such as for example a drag-cup motor, a pancake motor, or the like. With low dynamic demands it is also possible to employ some other type of motor, such as for example a brushless d.c. motor, a synchronous motor, or the like. In the case of a brushless d.c. motor, the electric motor 14 contains Hall sensors for the positive detection of its armature, for example in accordance with Fig. 8, and appropriate electronic switches for supplying the stator windings in accordance with the angle of rotation of the motor, which is for example excited by a permanent magnet. With such a motor the torque generated by the electric motor 14 at the shaft 13 corresponds to the operating current supplied via a supply line 15.

The shaft 13 is connected, either in the area between the electric motor 14 and the yarn delivery wheel 5, or alternatively at its end 16 which is remote from the yarn delivery wheel 5 and projects out of the electric motor 14, with an angle encoder 17, which is preferably designed as an incremental encoder or as an analog encoder with high resolution. His step number s is the number of steps which result in a single full resolution of the shaft 13. In this case the angle encoder 17 preferably has at least such a step number s that the ratio between the step number s and the diameter d of the windings 12 preferably is greater than three, preferably greater than five. In this way the error occurring in the detection of the rotated position of the yarn delivery wheel 5 lies below a limit which could cause tracks in the knit material, even with particularly hard (inelastic) yarns.

The structure of the angle encoder 17 is shown by way of

example in Fig. 4. In this case it is constituted by a synchro resolver having an armature with an armature coil 18, whose longitudinal axis extends transversely to its axis of rotation. In Fig. 4 the axis of rotation extends perpendicularly in respect to the drawing plane. The armature coil 18 is connected with a supply coil 19, which is axially oriented and which receives an a.c. excitation signal via a stationary outer coil, not further represented. Two stator coils 21, 22, whose coil axes are radially oriented and offset by 90°, detect the alternating field generated by the armature coil 18. The signal course represented in Fig. 5 result from this. Corresponding to the position of the armature coil 8, the amplitudes of the voltages generated in the stator coils 21, 22 increase or decrease in the shape of a sine or cosine. For example, in the case of an angle of rotation P, a positive voltage U_1 is induced in the stator coil 21, and in the stator coil 22 a negative voltage U_2. A conclusion regarding the angle of rotation P can be drawn from the voltages by means of the arc-sine or arc-cosine function.

An alternative embodiment of an angle encoder is represented in Fig. 6. It operates optically and has a first stationary disk 23 and a second disk 24, which is connected with the shaft 13. Both disks are respectively provided with a pattern of lines 25, 26, oriented in the radial direction. These form a light-dark pattern. The spaces provided between the lines 25 or 26 are preferably transparent. In a preferred embodiment the width of the lines and of the gaps between them are identical. The lines 25, 26 can also be slightly wider than the gaps. They furthermore agree in their number. If the angle encoder is intended to detect not only the number of revolutions, but also the direction of rotation, they differ in their number preferably by one.

A light source 27, for example in the form of a light diode, is provided for counting the steps, and is arranged on one side of the disks 23, 24. A light-sensitive element 28, for example a photo-resistor, a photo-transistor, or the like, is provided on the oppositely located other side. If the

direction of rotation is to be detected, one or two further such photoelectric barriers are provided, which pass light through the pair of disks at another location.

Fig. 8 illustrates another modified embodiment of an angle encoder with a rotatable permanent magnet M and four Hall sensors 21a, 21b, 22a, 22b arranged in the field of the latter. For example, these have been switched together as a bridge. Angle encoders of this type are installed anyway in some brushless electric motors, for example, in order to control electronic switches used for triggering the motor coil. If, by means of evaluating the voltages occurring at the Hall sensors 21a, 21b, 22a, 22b, such an angle encoder 17 allows the resolution of a revolution into a step number s, which is equal to or greater than the step number determined under the above discussed conditions, this angle encoder internal to the motor can be used as the position sensor for the connected control loop. The brushless d.c. motor becomes a virtual step motor in this way, which in contrast to the known step motors does not make any step errors, even if no particular changes in the rpm are taken into consideration. Such a virtual step motor can be operated in the start/stop mode, without meeting any special start-up regimens or shut-down regimens.

The signals emitted by the synchro resolver in accordance with Fig. 4 or the optical sensor in accordance with Fig. 5 are provided to a control loop 29 (Fig. 1) as actual position signals. A comparator 31 is a part of the latter, which compares the actual position signals from the angle encoder 17 with desired positions of a preselection unit 32. Each existing deviation between the desired position signal and the actual position signal is passed on as an angle error signal via a branch 33 to a regulating circuit 34, which controls the electric motor 14 correspondingly in order to bring the desired position signal and the actual position signal into agreement.

The actual position signals of all yarn delivery devices 1 to 3 can be optionally conducted via appropriate lines 35 to the control device 4. In this case the lines 35 can directly

pass on the signals from the angle encoders 17 in that they connect the angle encoders 17 with the control device 4. It is also possible to lay out the lines 35 as a data bus, which is connected via appropriate interfaces to the angle encoders 17. This includes all existing data buses, also single wire buses.

The control device 4 sends control pulses 36 to the preselection unit 32 via a line 36. Thus the yarn delivery devices 1, 2, 3, which are to be operated parallel, can be parallel controlled. In the present exemplary embodiment the control unit 4 issues individual pulses, wherein each single pulse of the rotation of the electric motor 14 by one step corresponds to the angular resolution of the angle encoder 17. If the angle encoder 17 is constructed in accordance with Fig. 4, for example, and if it contains an evaluation circuit connected to the stator coils 21, 22, which converts the signals derived from the stator coils 21, 22 into a signal of analog or digital nature, which unequivocally characterizes the angle of rotation, the preselection unit 32 is also correspondingly embodied. In this case it has a counter, for example, which respectively counts from zero up to the maximum number of steps of the angle encoder 17, and then starts over again. In this way an analog or digital step-shaped signal of the appropriate number of steps is created from the individual step pulses delivered via the line 36. As soon as pulses are delivered via the line 36, the electric motor 14 rotates. If no pulses arrive, it stops. Observed from the outside, in this way the electric motors 14 behave like step motors, which perform an angular step for every pulse delivered via the line 36. But as a result of the internal position regulation they are not subject to step errors so that, different from common step motors, they can be started and stopped without problems.

The yarn delivery devices 1 to 3 delivered up to now operate as follows:

It is assumed that the yarn delivery devices 1 to 3 are provided for a knitting machine, which is designed, for example, as a Jacquard knitting machine or as a knitting machine with a striping attachment. Each yarn delivery device

1, 2, 3 supplies a knitting station with a respective yarn 9. If the respective knitting stations are to be supplied with yarn, the control device 4 sends pulses to the appropriate preselection units 32, whereupon the yarn delivery wheels 5 rotate appropriately. In the course of this they follow the preset signal true to the angle, wherein existing angular deviations in relation to the circumference of the yarn delivery wheel are less than 1 mm, but preferably less than 0.6 mm. This is a result of the requirement that the ratio s/d is greater than three, preferably greater than five, per millimeter. By means of this it is achieved that possible angular errors fall below other error effects. The sliding movement of the lap 11 on the yarn delivery wheel 5 in particular can be a part of such error effects. As long as the yarn delivery wheel 5 rotates, the lap 11 is downwardly displaced by means of the incoming yarn 9 in the direction of the unwinding yarn. Because of the existing axial sliding movement, a certain slippage of the lap 11 in the circumferential direction also occurs, of course. This means that a certain slippage of the yarn on the yarn delivery wheel 5 occurs. It is preferred if the quotient of the circumference of the yarn delivery wheel and the angular resolution s is less than this slippage, for example less than 1 mm, preferably less than 0.6 mm. A knitting machine equipped with such yarn delivery devices 1 to 3 can be started up from a stop, stopped again and again started, without creating standing rows, i.e. rows of stitches of a different sizes.

The delivery speed of the yarn 9 can be increased, reduced or set to zero by means of the specific delivery of pulses via the line 36. Thus, positive yarn delivery is possible in connection with Jacquard knitting machines.

Expanding the embodiment so far described, the yarn delivery devices 1 to 3 can be provided with yarn tension sensors 37, which monitor the tension of the unwinding yarn. For example, the tension sensors can be connected with the preselection unit 32 in order to affect the allowance of the yarn. Otherwise, the above description correspondingly

applies. The same reference numerals are being used. It is possible in connection with this embodiment to operate the yarn delivery devices 1, 2, 3 in a tension-regulated mode of operation, if required. For example, a yarn tension signal is delivered via the line 36. The preselection unit 32 compares this with the actual tension determined by means of the yarn tension sensor and creates an appropriate desired position signal. This is in turn converted by the control loop 29 into revolutions of the yarn delivery wheel 5.

Such a yarn delivery device 1 to 3 can operate alternatively as a positive yarn feeding device or as a tension- guided yarn feeding device, i.e. can deliver yarn at a constant delivery rate or a constant yarn amount.

Fig. 7 illustrates a complement for the yarn delivery device 1 to 3 in accordance with Fig. 2. Here, the preselection unit 32 and the regulating circuit 34 have been combined into a position regulating device 38. At one input 39, the latter receives a tension preselection signal. It receives an actual tension signal from the yarn tension sensor 37. At a further input, the angle encoder 17 delivers an actual position signal. The moment driving and accelerating the yarn delivery wheel 5 is detected by means of a current sensor 41 and reported back to an input 42 of the tension regulator 38. Thus, the tension regulator 38 receives signals regarding the speed of the running yarn, the accelerating or braking torque acting on the armature of the motor, and the yarn tension. It is embodied as a PD regulator. An error signal is formed from the yarn speed, the yarn tension and the motor current, which is applied to the PD regulators in the form of a disturbance variable. In this way a robust regulator is created, whose regulating deviation is small for nearly all occurring yarns, regardless of their elasticity, and which very rapidly follows changes in the preset signal at the input 39.

Fig. 3 illustrates a further development of the yarn delivery device 1 to 3, based on the embodiment in accordance with Fig. 1. Initially, reference is respectively made to the description of the exemplary embodiment in accordance with Fig.

1, including Figs. 4 to 6. The following applies in amplification:

The regulating circuit 34 has an additional control input, at which it can be deactivated as a regulating circuit and changed to a dragging mode of operation. This control input is connected with the control device 4 via lines 43 or an appropriate bus. As soon as the regulating circuit 34 receives an appropriate signal via the lines 43, it changes into a dragging mode of operation. In this, the electric motor 14 is charged with a low current, which is at least sufficient to overcome possible locking moments of the electric motor 14. The latter is then "invisible" as far as the yarn delivery wheel 5 is concerned, i.e. it does not hamper a rotation of the yarn delivery wheel 5 because of a pull on the yarn 5. This corresponds to a virtual uncoupling of the electric motor 14 from the yarn delivery wheel 5. In this state the individual yarn processing positions (knitting systems) can themselves obtain yarn without being prevented from doing so by the electric motors. The control device 4 registers the amount of yarn obtained via the lines 35. A preselection value can be determined from the detected values, which in the course of a subsequent positive operation is delivered via the line 36 in the form of appropriate control pulses.

It is also possible to create a slight driving torque in the dragging mode of operation in order to make it easier for the knitting stations to obtain yarn. However, the moment, or the control currents of the electric motors 14, are so low that no individual yarn conveyance as a result of supplying the electric motors 14 with current takes place.

The high resolutions of the angle encoders 17 which exist in addition to possible sensors at the electric motors, such as Hall sensors, for example, also have a positive effect in the course of detecting the amounts of yarn obtained by the knitting stations. Regarding the measurement of the natural yarn usage in the dragging mode of operation it is possible to provide a complete freedom from stopping moments, something which is hardly possible with conventional step motors.

A yarn delivery device is provided with a motor-driven yarn delivery wheel, wherein the rotated position of the yarn delivery wheels is detected with high precision by means of an angle encoder. The angle encoder has at least a resolution s which is greater than the circumference of the yarn delivery wheel 5, measured in millimeters. The resolution s is preferably greater than five times (preferably 5.24 times) the value of the diameter of a winding of the yarn delivery wheel. The yarn delivery wheel is preferably looped by several (three to twenty) windings.

List of Reference Numerals

1,2,3	Yarn delivery devices
4	Control device
5	Yarn delivery wheel
6,7	Edge
8	Ribs
9	Yarn
11	Lap
12	Winding
13	Shaft
14	Electric motor
15	Feed line
16	End
17	Angle encoder
18	Armature coil
19	Supply coil
21, 22	Stator coils
21a,21b,22a,22b	Hall sensors
23, 24	Disks
25, 26	Lines
27	Light source
28	Element
29	Control loop
31	Comparator
32	Preselection unit
33	Branch
34	Regulating circuit
35	Lines
36	Line
37	Yarn tension sensors
38	Tension regulator
39	Input
41	Current sensor
42	Input
43	Lines

P	Angle of rotation
d	Diameter
s	Step number
M	Permanent magnets
U_1, U_2	Voltage